Report 2

REPORT
Effects of Control Methods on the *Egeria densa* Community

Steven Obrebski, Terry Irwin and Jennifer Pearson
Romberg Tiburon Center San Francisco State University
P.O. Box 855, Tiburon, CA
94920

Introduction

The purpose of this study was to develop and apply methods for sampling *E. densa* and its fauna that could provide data that would be used to evaluate the effects of different control methods on this biological community. Methods for quantitative sampling of *E. densa* density, abundance of the fauna inhabiting the *E. densa* community, and abundance of bottom (benthic) organisms in *E. densa* beds were developed in the fall of 1997 and modified in the winter and spring of 1998. Owing to the rarity of benthic organisms in the community, and the high abundance of organisms associated with *E. densa*, benthic sampling was discontinued in 1998.

This report summarizes information on

(a) Trends in *E. densa* growth between April and August, 1998.
(b) Estimation of the effects of control methods on *E. densa* biomass.
(c) Description of fauna inhabiting *E. densa* beds.
(d) An outline of analytical problems associated with determination of the effects of conrol methods on *E. densa* fauna.
(e) Description of seasonal changes in *E. densa* fauna.

The present report is a summary of some results of an extensive graphic and statistical analysis of the data. It does not include analysis of faunal samples obtained in 1997 using earlier, less efficient methods for sampling *E. densa* and its fauna. In spite of the sampling effort applied, variation in the data, and small sample size reduce the power of the methods used to discern differences in abundance of the plant and its resident fauna. The results of continuing multivariate analyses of the data will be reported elsewhere. A summary of the major findings occurs on page 11.

Sampling Methods

Field samples were taken using a specially designed craft constructed for deployment of a large core sampling device. The craft was made from two canoes arranged as a catamaran, equipped with a hatch in the middle, through with the core device, suspended from an A-frame, could be lowered. The plant was sampled with an eight foot long, 22.5 inch diameter core, sampling 0.25 square meters that was lowered to the substrate, penetrating it up to 12 inches. *E. densa* enclosed in the core was uprooted by rotating a rake pushed into the substrate. Plants and plant fragments were carefully removed. Wet weight of the plant , time of sampling and depth were recorded. Fauna were retrieved by washing the entire plant sample in 5 gallons of water using a standard washing procedure and passing the wash water through a 0.355mm sieve. A 7 gallon pump sample from mid-depth in the core was also taken to obtain organisms released into the water column. This sample was poured through a 0.333 mm screen before preservation. The faunal samples were preserved in 2.5% formaldehyde solution. Usually seven random samples were taken in each study site, although sample numbers varied from 3 to 14 cores. Two samples per study site were usually used to extract fauna. All *E. densa* samples were put into plastic bags and transported to the laboratory where dry weights were obtained by drying the plants to constant weight at 80° C. Organisms were transferred to 70% alcohol, picked, identified to the lowest possible taxon, and counted. Samples with large numbers of organisms were split in a plankton sample splitter and counts were then adjusted according to the fraction of the sample used. Water column samples usually contained small numbers of organisms and were not used in this study.

Random sample placement was approximate. Exact sample placement could not be practically achieved by using a predetermined random sampling location procedure owing to difficulties in maneuvering the craft in high wind conditions, and problems encountered in penetrating thick patches of the plant. It was sometimes necessary to force the craft into dense *E. densa* beds to obtain samples. During high wind periods, the craft was anchored at the windward part of the sampling site, and successive samples were taken at locations determined by letting out more anchor rope and allowing the craft to drift downwind.

During the 1998 field study period, 500 core samples were taken and processed. A total of 141 samples of fauna directly associated with the plant and 141 pump samples of the water column enclosed in the sampling core were also taken and processed. The numbers of samples taken and processed exceeded initial specifications.

Fauna Associated With *E. densa*

The organisms associated with *E. densa* are listed in Table I. Organisms that were identified to genus are probably represented by one species. Groups not identified to genus such as ostracods and copepods consist of several species. Other groups may or may not be represented by more than one species. Keys used in identification are listed in Table I. None of the species or groups listed were found on the list of rare or endangered species of California.

This fauna is probably characteristic of freshwater attached macrophytes in the continental United States. The five most common taxa were Dipteran larvae, the amphipod *Hyalella azteca*, Cladocera, the snails *Physa sp.* and *Gyraulus sp.* and the oligochaete *Stylaria*.

Study Areas

Maps of the study localities and treatment sites are shown in Figures 1 and 2. The study localities included Venice Island, Franks Tract, Big Break, Owl Harbor/7-Mile Slough, White Slough and Sandmound Slough. Treatment sites within each locality are labeled as control or treatment sites. Treatment sites were those in which a control methodology such as mechanical harvesting or chemical application was used. Control sites were untreated. Sites within localities where mechanical harvesting and immediately adjacent control experiments were performed are labeled as harvest areas. A site labeled as the 7-Mile Slough Control Area in the Owl Harbor/7-Mile Slough locality was situated just outside of the Owl Harbor channel and served as a control area for the chemical treatments used within the Harbor. Similarly, a chemical control site was designated in White Slough. The location of these control sites within localities was arbitrary. Ideally, site selection would occur after the distribution of the plant in the different localities was understood and control sites would be chosen to match the treatment sites in *E. densa* density, depth, and other site characteristics. This would have added considerably to the duration and cost of the field program and was not done.

Trends in *E. densa* Density

Background seasonal changes in *E. densa* density need to be understood to evaluate the impact of control methods on changes in the density of the plant. By *E. densa* density we mean the dry weight of *E. densa* per core sample, or the dry weight per 0.25 square meter, the area sampled by the core device. Seasonal trends in the density of *E. densa* were determined from samples taken in three localities: Owl Harbor, Sandmound Slough and White Slough. The data used consists of samples taken at different times in different sites within each locality. Ideally, documentation of seasonal growth rates requires sampling at regular and contemporaneous intervals at all sites within a particular locality. This was precluded by the demands of the rapidly developing field program. For each locality the data consists of samples from different sites, none of which was regularly sampled throughout the spring and summer during which field work occurred. Moreover, all sites that had been subjected to chemical or mechanical treatment were excluded from the analysis of seasonal trends, including those that had been mechanically harvested in 1997, because earlier analysis showed that these sites had lower densities in the spring of 1998 than corresponding unharvested control sites.

It is assumed that the seasonal growth patterns of the plant may differ between sites within localities, but with the data available, it is not possible to determine definitively if this is the case. For example, in Owl Harbor, (Fig. 3), samples were obtained in an unharvested control site, a chemical control site in 7-Mile Slough just outside the mouth of the harbor channel, and several chemical (Reward and Komeen) pre-treatment sites. Note that a gap exists in June and July when samples were not obtained in the unharvested control site for which no seasonal trend is apparent. A decline in *E. densa* density in July and August is suggested by the chemical control site data. Assuming that the aggregate data represents growth under homogeneous conditions, the results suggest that *E. densa* density increased in the spring to a maximum in June and then declined.

In Sandmound Slough (Fig. 4) the composite site data suggest an increase to maximal density in late May, followed by a decline to densities observed in the fall of 1997. White Slough has a similar pattern of change (Fig. 5).

Note that in all cases, *E. densa* densities in August were comparable to densities observed at these sites in October and November 1997. The aggregate data suggest that *E. densa* grew to maximum densities in late May through June, and declined subsequently to levels observed in the previous fall. Owing to the exceptional weather in 1998, these data provide only approximate estimates of growth. The results suggest that the plant may have been declining during a good part of the period during which control methods were being applied.

Effects of Control Methods on *E. densa* Density

As indicated in the previous section, there is some evidence that *E. densa* density was declining during most of the experimental period. Therefore, evaluations of the effects of various control methods on the plant must take into account natural changes in both treatment and control sites. To contrast the effectiveness of different control methods, changes in mean *E. densa* densities in control and treatment areas were compared by calculating the percent change in mean plant densities in treatment areas adjusted for temporal changes observed in the control areas (Table II). This was done by subtracting the percent change in the control area from the percent change in the treatment area. The resulting "Adjusted %" is a measure of the relative effect of the treatment (such as mechanical harvesting) on *E. densa* density after adjusting for declines or increases in densities in the control area. The control area provides an estimate of trends in the plants density during the observation period before and after treatment. Large negative Adjusted percentages indicate that the treatment was effective in decreasing *E. densa* density and/or suppressing its growth. Note that *E. densa* tended to decline in the control areas during the experimental intervals listed (Table II). As shown in the previous section, *E. densa* densities have declined this summer to values approximating those observed in the fall of 1997.

Because of the relatively small sample size used in these site surveys, it is possible that a set of samples may grossly underestimate or overestimate *E. densa* biomass. Very few of the changes reported are significant owing to the large variances and small sample size. Variances could not be pooled over sites and between times to provide more sensitive tests. The effects of harvesting varied between sites and times. Harvesting was ineffective in Owl Harbor in the fall of 1997. In Sandmound Slough and White Slough harvesting in the spring and summer of 1998 was more effective than in the fall of 1997. The large effect of harvesting (-159%) observed in White Slough may be due either to growth of *E. densa* in the control site or anomalous sampling in dense patches of the plant. Several Komeen and Reward treatments were applied in Sandmound Slough, but the first were so effective that subsequent samples in the treatment area showed that *E. densa* biomass had been reduced to near zero values. Therefore the second set of treatments was not evaluated. It is possible that the effects of both Reward and Komeen were confounded in the Sandmound chemical treatment area, and the observed effects are the results of a combination of both chemicals. The first Reward treatment in Owl Harbor was not evaluated because the treatment area sampled was behind a dock where flow and application of the agent was greatly reduced. The initial Komeen treatment in Owl Harbor was also so effective in reducing densities of the plant that subsequent treatments also could not be evaluated.

The results in Table II generally suggest that Sonar seemed to be least effective in reducing *E. densa* density. Komeen was most effective in Owl Harbor and Sandmound Slough. Mechanical removal and Reward application produced the best results in White Slough.

Faunal Abundance and *E. densa* Density

Methodological Considerations

It is assumed that the abundance of most fauna associated with *E. densa* should be positively correlated with the density of the plant owing to the direct dependence of the organisms on the plant. For example, snails, hydras, flatworms, oligochaets, and other worms and larval insects live directly on the plant leaves or stems. Copepods, cladocerans, ostracods, and other organisms that can swim may nevertheless be entrained in thick *E. densa* stands, although their correlation with *E. densa* density may decrease as the stands become less dense or patchy in distribution.

Description of the relationship between the number of organisms and *E. densa* weight is important for the evaluation of changes in faunal abundance resulting from changes in density of the plant. In a typical example shown in Table III, data from White Slough is pooled over sampling times and areas. Most correlation coefficients between the numbers of a particular species and dry weight are positive, and all significant correlations are positive. Some of the high correlations between fauna and *E. densa* weight are remarkable because the data are composites taken at different times and in different areas in the locality.

The positive correlation between faunal abundance and *E. densa* density complicates comparisons of faunal abundance between areas or times because the weights of the samples of *E. densa* used to estimate faunal abundance are not likely to be equal in the sampling areas being compared. Therefore, statistical comparisons between treatments must include the dry weight of the plant as a covariate as in the analysis of covariance.

Since the correlations tend to be positive, a reduction in *E. densa* biomass would be expected to result also in a reduction of the abundance of the fauna, other things being equal. But if the *E. densa* samples taken in a treatment site for faunal analysis contained more *E. densa* than the samples taken in a control site, the treatment site may actually show an increase in the fauna, even though *E. densa* densities have decreased in the treatment site. If samples used in comparisons are not equal in weight, they can be normalized by dividing the numbers of individual species or the total fauna by the weight of the sample, yielding estimates of density of organisms per unit weight of *E. densa*. However, this approach involves the assumption that the correlation between faunal abundance and *E. densa* density is represented by the same linear relationship in the treatment and control areas. This is not necessarily true as shown in the examples discussed below.

More detailed analyses show that the relationship between the number of organisms and *E. densa* dry weight may also vary between localities and times. This is apparent in samples were taken in White Slough in three sites (Fig. 6). These were a chemical control site (C), a mechanical control and harvesting site (M), and a site where chemical treatments were applied (T) (see map in Fig. 2). Samples were divided into two time periods, May/June and July/August. The results (Fig. 6) show that there are two different linear relationships between the number of organisms and dry weight. The chemical control site had a linear relationship having a low slope which did not change with time. Other sites had relationships that were less stable in time, fluctuating between the two extremes. We are at a loss to explain this phenomenon.

Other examples of relationships between the total number of organisms and *E. densa* are summarized in Figs. 7 – 10. These results suggest that the total abundance of organisms and the abundance of *Hyalella azteca* and *Dugesia* tend to be lower than in sites from the Owl Harbor channel. The data in Figs. 7 – 10 were analyzed using the GLM procedure where abundance was related to a coded site variable (harvested vs. unharvested, Owl Harbor channel vs. chemical control site) with dry weight used as a covariate. Although the plots are suggestive, no significant differences were found. Likewise analysis of variance for differences between sites, after conversion of the data to numbers per unit weight was not significant. These results are typical of many suggestive comparisons made in this study. The data are insufficiently replicated and quite variable, lacking power to detect differences.

Effects of Removing *E. densa* on Faunal Abundance

When the dry weights of samples are homogeneous over treatments and times, the effects of reduction in *E. densa* density on faunas can be investigated directly. The following analysis examines the effect of mechanical harvesting at White Slough. This site consists of two adjacent areas, one subjected to mechanical removal and the other serving as a control (located in the area labeled HARVEST on the map in Fig. 2. Four samples from each area were taken during the two time periods (May/June, July/August). The raw data and means are summarized in Fig. 11. Two way analysis of variance showed that the average dry weights of the samples differed significantly among treatment areas (harvested versus unharvested, $F_{(1,12)} = 23.17$, $p < .001$) but not times. As a consequence the harvested and unharvested area samples from different times were pooled to determine the average abundance of different species in each area. The average of each taxon and the total numbers of organisms was calculated for the harvested and unharvested samples. Then, for each taxon, the average abundance in the harvested area divided by the average abundance in the unharvested area was calculated to produce a ratio which shows the degree to which the abundance in the unharvested ratio was reduced. If no reduction in the treatment area occurred, this ratio would be 1. If the fauna increased this ratio would exceed 1. If the effects of a control method not only reduced the fauna because of reduction of *E. densa* biomass, but also because the treatment poisons the fauna as well, then the ratio might be lower than the ratio of treatment/control *E. densa* biomass.

The results are summarized in Table IV. The average ratio for the 17 taxa listed in the table is 0.543. Is this ratio significantly different for 1, as would be expected if no reduction had occurred? This can be crudely tested with a Students t-Test to determine if the observed average ratio is significantly different from 1. The results are highly significant ($T = -6.16$, $p < 0.0001$). Note also that the degree of reduction in the average number of each species, as well as the total number of individuals of all species, is generally not as great as the reduction in average dry weight of *E. densa* from which these faunal samples were obtained. That, is the HARVESTED/UNHARVESTED dry weight ratio was 0.310, while the average ratio for the 17 faunal groups (excluding the TOTAL) is 0.562 which is significantly higher than 0.310 (Students t-Test, $p = 0.0051$). This suggests that the reduction in the fauna was not directly proportional to the estimated reduction in *E. densa* biomass. Average faunal abundance did not decrease as much as *E. densa* biomass.

Changes in Faunal Composition

Various methods were used to describe spatial and temporal variations in *E. densa* faunal distributions. Samples from the chemical control area in Owl Harbor/7-Mile Slough were used to examine seasonal changes in faunal composition. The number of each taxon in each sample was normalized by dividing it by the dry weight of that sample to produce a calculation of the density (number/gram) of the taxon per unit dry weight of *E. densa*. Samples taken at the same date were then averaged. The resulting mean abundance was divided by the total of the means for all the taxa and multiplied by 100. This produced an estimate of the percent of the total fauna represented by each taxon at each date. The results (Fig. 12) show that instability in faunal composition can occur over time. Shifts in numerically dominant species are frequent. However, considerable stability may exist over larger spatial scales, as will be shown below.

The method described above was used to examine the effects of Sonar treatment on the fauna in Big Break. Percentages of different taxa in control and treatment sites in June and August are tabulated in Fig. 9. Although the control site was located outside of the Big Break harbor area, about one kilometer to the east of the Big Break Marina entrance, the *E. densa* fauna at both sites was exceedingly similar in June, 1998, with a highly significant correlation between percentages of 0.967 (Figs. 13, 14). Correlations within sites between the two sampling times were low and not significant (Fig. 14). Note that in some groups, such as *Hydra* and the amphipod *Hyalella azteca*, percentages did not change substantially over time or between sites, while other species, such as the snail *Physa*, declined between June and August. This snail also declined in 7-Mile Slough after early July suggesting that the occurrence of this species may be a seasonal event in some localities.

Seasonal Changes in *E. densa* Fauna

As indicated above, the abundance of organisms on *E. densa* tends to increase with the dry weight of the sample, although correlations between total abundance and plant weight can vary widely between different sites and dates. In order to compare the abundance of organisms in any pair of samples, it is necessary to normalize the abundance to some common unit. To do this we divided the abundance of each species in a sample by the dry weight (in grams) of *E. densa* from which the organisms were obtained. For each sample this yielded a list of numbers of individuals of each species per gram of the plant. The similarity of any pair of samples could then be determined using a statistic like the correlation coefficient. That is, correlations between the numbers of individuals per gram for the suite species in any pair of samples could be calculated. Furthermore, the samples could be grouped according to their levels of similarity using a technique called Cluster Analysis.

Cluster analysis is a method used widely in ecology and systematics to classify samples into groups when the groups are unknown (Jongman et. Al, 1995, Minitab Users Guide 2, 1998). The method can be used to classification of species, sites or variables and is often more informative that other multivariate techniques. In the present application we are interested in the concurrence of species in the *E. densa* community at different times and in different locations at particular sampling sites. For example, are groups of samples taken in the late summer more similar to each other in numerical species composition, than they are to another group of samples taken in the spring and early summer? If that is the case, the we can conclude that there has been a seasonal change in species composition. In the present application an agglomerative method was used.

This method involves combining samples on the basis of some similarity, such as the degree of correlation between them. A single sample is united with another sample that is most closely correlated with it. These two samples are then combined and united with an additional sample that is most closely related with the combined pair. Alternatively two other closely related samples are united into a separate group, and so on. The correlation between groups of samples can be used as a measure of the similarity between them. Various methods for liking groups can be used. The method yields a groups or clusters of samples according to their level of similarity and the results can be plotted on a dendrogram (Fig. 15.) where samples are arranged according to the level of similarity between them. The similarity measure depends on the method used to link groups of samples together.

The samples in Fig. 15 are identified according to location, treatment category and date. Thus, M-7/21 refers to a sample taken in the chemical control site just outside of Owl Harbor/7-Mile Slough on July 21, 1998. Note that the upper dendrogram in Fig 15 shows this sample to be quite dissimilar to all the other samples as indicated in the dendrogram by the low similarity (73.35) between that sample and all the others. Note also that there are two major clusters of samples which appear to belong to two date or time related groups. The first consists of samples U-4/28, U-5/27, RB1-5/27, and H-4/28. The second consists of 11 samples with dates between 6/17 and 8/18, which are more similar among each other than to samples in the first group. This suggests that there are two temporal groups of samples, one characteristic of April and May, and the other of June, July and August samples. Inspection of the abundance distribution of species in the samples indicated that the snail *Ferrisia* was extremely abundant in sample M-7/21. When the abundance of this snail was removed from all the samples and the dendrogram recalculated, as shown in the lower dendrogram in Fig. 15, sample M-7/21 becomes firmly embedded within the second, July/August group of samples.

Different linkage methods for grouping samples can yield different results. In Fig. 15, the results of Single Linkage are shown. In Fig. 16, the data are treated similarly but the Average Linkage method is used. Note that this method now places sample KB-6/17 firmly in the April, May group of samples. The Average Linkage method is commonly used in ecological applications. Various other linkage measures were used, yielding the same results. The Average Linkage method is frequently used in ecology.

The results summarized in Figs 15 and 16 indicate that there was a shift in fauna in Owl/Harbor/7-Mile Slough from a more loosely connected group of organisms characterizing the April-June samples, to a more strongly connected group sampled in July and August. That is, there was a seasonal change in faunal composition in Owl Harbor. Note also that samples taken in areas subject to the application of various *E. densa* control treatments do not appear to be dissimilar from samples obtained in the treated areas. For instance, samples H-8/3 and H-7/21, KA-7/1, RA1-7/, taken from areas subjected to mechanical harvesting, Komeen and Reward application, respectively, are closely similar to the other samples taken in July and August. This suggests that the faunal composition in these treatment areas was mainly influenced by seasonal factors.

Similar cluster analyses have been applied to data from Sandmound Slough and White Slough. In Sandmound Slough (Fig. 17) more temporally heterogeneous clusters emerged from the analysis, with one major group consisting of May, June and July samples, and the other containing July and August samples. In White Slough (Fig. 18), one cluster consisted of May, June and July samples, and the other of May, July and August samples.

The foregoing results suggest that there are seasonal shifts in the composition of the fauna inhabiting *E. densa* beds, but their magnitude may vary between different areas in the Delta. There is insufficient data from other localities to determine if there is any predictable variation (possibly from the western to Eastern Delta) in these seasonal faunal transitions.

Changes in *E. densa* fauna in Owl Harbor are summarized in Fig. 19 where the percent of each taxon is shown for April/May, June and July/August. The percentages were calculated by averaging the abundance for each time period, and expressing it as percent of the total abundance. Changes include reduction in the relative proportion of *Stylaria, Physa* and *Diptera*, and increases in *Hyalella azteca, Ferrisia* and *Dugesia*. June appears to be transitional between the earlier and later time periods.

Similar description of faunistic changes in Sandmound Slough and White Slough did not yield easily interpretable results. The percent faunal composition depended on how groups of samples were combined, and no stable results could be obtained.

Summary of Results

Trends in mean density of *E. densa* suggest that maximum densities occur in late April and June, declining thereafter. Densities declined to values found in the fall of 1997. Since 1998 weather was anomalous, accompanied by rain, siltation, and cool temperatures, the trends observed may not be characteristic of growth of the plant in the Delta in normal years.

Sonar seemed to be least effective in reducing *E. densa* density. Komeen was most effective in Owl Harbor and Sandmound Slough. Mechanical removal and Reward application produced the best results in White Slough.

None of the species or groups listed were found on the list of rare or endangered species of California

The relationship between faunal abundance and *E. densa* dry weight varies between areas within localities and times. This variation and small sample size limits the power to discern changes in faunal abundance.

There are seasonal shifts in the composition of the fauna inhabiting *E. densa* beds, but their magnitude may vary between different areas in the Delta. There is insufficient data from other localities to determine if there is any predictable variation (possibly from the western to Eastern Delta) in these seasonal faunal transitions.

Literature Cited

Jongman, R.H.G, C.J.F. Ter Braak and O.F.R. Van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press.

Minitab User's Guide 2: Data Analysis and Quality Tools, 1998. Minitab Inc.

TABLE I

Egeria densa ASSOCIATED FAUNA

PHYLUM/CLASS/ORDER			FAMILY	GENUS
Coelenterata				*Hydra*
Platyhelminthes				*Dugesia*
Nemertea				*Prostoma*
Bryozoa				*Plumatella*
Mollusca			Physidae	*Physa*
			Planorbidae	*Gyraulus*
			Ancylidae	*Ferrisia*
Annelida	Oligochaeta		Naididae	*Stylaria*
				Chaetogaster
			Tubificidae	*Tubifex*
			Hirudinea	*Helobdella stagnalis*
				Helobdella fusca
Arthropoda	Crustacea			
		Amphipoda		*Hyalella azteca*
				Corophium
		Ostracoda		
		Copepoda		
		Cladocera		
			Moinidae	
				Moinodaphnia
			Sididae	
				Sida
			Chydoridae	
				Eurycercus
				Psuedochydorus
Insecta	Odonata		Zygoptera	
	Tricoptera			
	Diptera			
			Culicoidea (midges)	
Arachnida	Hydracarina			

Keys used in identification: (1) Bohrer, D.J. et al. 1976. An introduction to the study of insects. Holt, Rinehart and Winston, N.Y. 4th Edition. (2) Eddy, S. & A.C. Hodson, 1961. Taxonomic Keys to the Common Animals of the North Central States. Burgess Publishing Co., Minneapolis, Minn. (3) Pennack, R.W. 1953. Freshwater Invertebrates of the United States. The Ronald Press. Co. NY. (4) Thorpe, James H. & Allan P. Kovich, 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. NY.

TABLE II
Effects of Control Methods on Dry Weight Biomass

Effects of Mechanical Harvesting on *Egeria densa*

Locality/Date(Before-After)	Harvest %	Control %	Adjusted %
Owl Harbor			
10/97-11/97	-14%	-40%	+26%
4/98-5/98	-11%	-16%	+4%
7/98-8/98	-11%	-16%	+5%
Sandmound Slough			
10/97-11/97	-62%	-22%	-44%
4/98-5/98	-82%	-23%	-59%
7/98-8/98	-90%	-23%	-67%
White Slough			
10/97-11/97	-60%	-34%	-26%
4/98-5/98	-44%	+114%	-158%
7/98-8/98	-41%	+20%	- 61%

Effects of Sonar on *Egeria densa*

Locality/Date(Before-After)	Sonar %	Control %	Adjusted %
Big Break 6/98-8/98	-80%	-45%	-35%
Franks Tract 6/98-8/98	+37%	-60%	+97%
Venice Island 6/98-8/98	-31%	-55%	+24%

Effects of Komine on *Egeria densa*

Locality/Date(Before-After)	Komine%	Control %	Adjusted %
Owl Harbor 6/98-7/98	-97%	+8%	-106%
Sandmound Sl. 6/98-7/98	-96%	+16%	-112%
White Slough 6/98-7/98	-68%	-43%	-25%
White Slough 6/98-7/98	-100%	-53%	-47%

Effects of Reward on *Egeria densa* *

Locality/Date(Before-After)	Reward%	Control %	Adjusted %
Owl Harbor 7/98-8/98	-100%	-36%	-64%
Sandmound Sl. 7/98-8/98	-90%	-23%	-67%
White Slough 6/98-7/98	-27%	-13%	-14%

TABLE III.

CORRELATIONS BETWEEN FAUNAL ABUNDANCE AND DRY WEIGHT IN *EGERIA* SAMPLES FROM WHITE SLOUGH

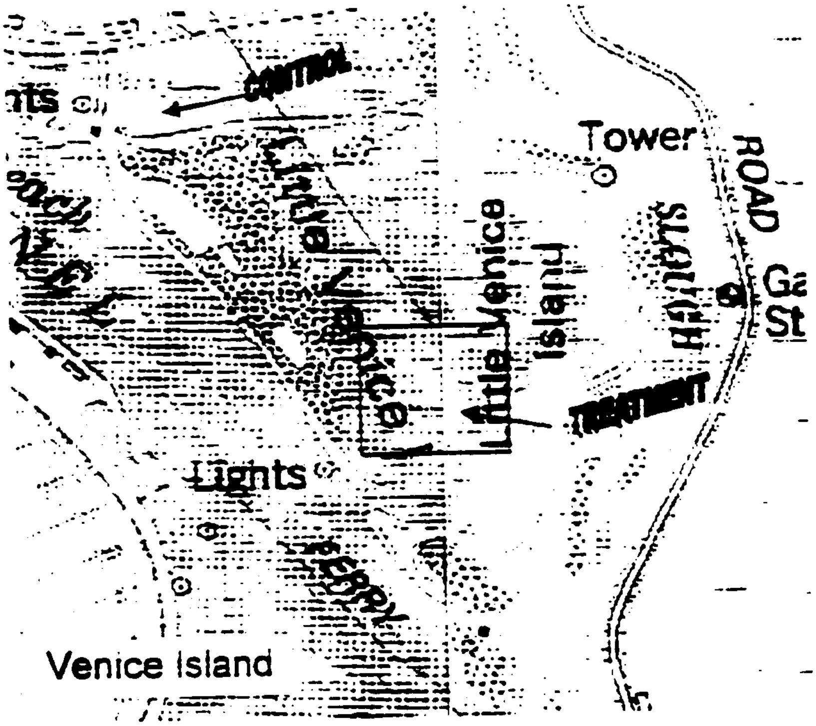
Hydra	0.239	Stylaria	0.452	Hyalella	0.816*
Dugesia	0.165	Chaetogaster	0.306*	Corophium	-0.055
Physa	0.786*	Tubifex	-0.169	Ostracoda	0.361*
Gyraulus	0.580*	H. stagnalis	0.084	Copepoda	0.411*
Ferrisia	0.013	H. fusca	-0.138	Cladocera	0.312*
Odonata	0.368*	Tricoptera	0.105	Diptera	0.178
Acarina	0.422*	TOTAL	0.520*		

* = Correlation signifcantly different from 0.

TABLE IV.

AVERAGE NUMBERS OF ORGANISMS IN HARVESTED AND UNHARVESTED AREAS

SPECIES	HARVESTED	UNHARVESTED	H/UH RATIO
Hydra	22.25	92.75	0.240
Dugesia	134.00	167.00	0.802
Bryozoa	24.20	146.00	0.166
Physa	54.50	230.00	0.237
Gyraulus	49.75	75.75	0.657
Stylaria	57.50	149.00	0.386
Chaetogaster	4.50	5.00	0.900
Tubifex	11.00	19.50	0.564
H. stagnalis	13.25	31.00	0.427
Hyalella	179.50	513.50	0.350
Ostracoda	11.50	46.00	0.250
Copepoda	14.50	43.50	0.333
Cladocera	146.30	276.00	0.530
Odonata	4.00	5.00	0.800
Tricoptera	50.00	37.00	1.351
Diptera	1042.00	1369.00	0.761
Hydroacarina	14.00	29.50	0.475
TOTAL FAUNA	1842.00	3275.00	0.562
EGERIA DRY WEIGHT (Grams)	9.04	29.20	0.310



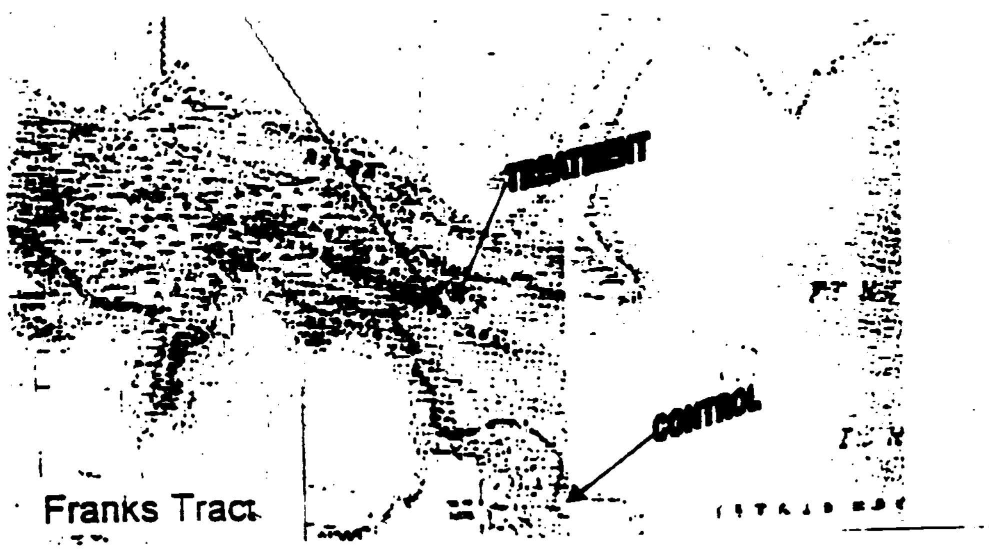


Fig. 1. Control and treatment site locations in Venice Island and Franks Tract.

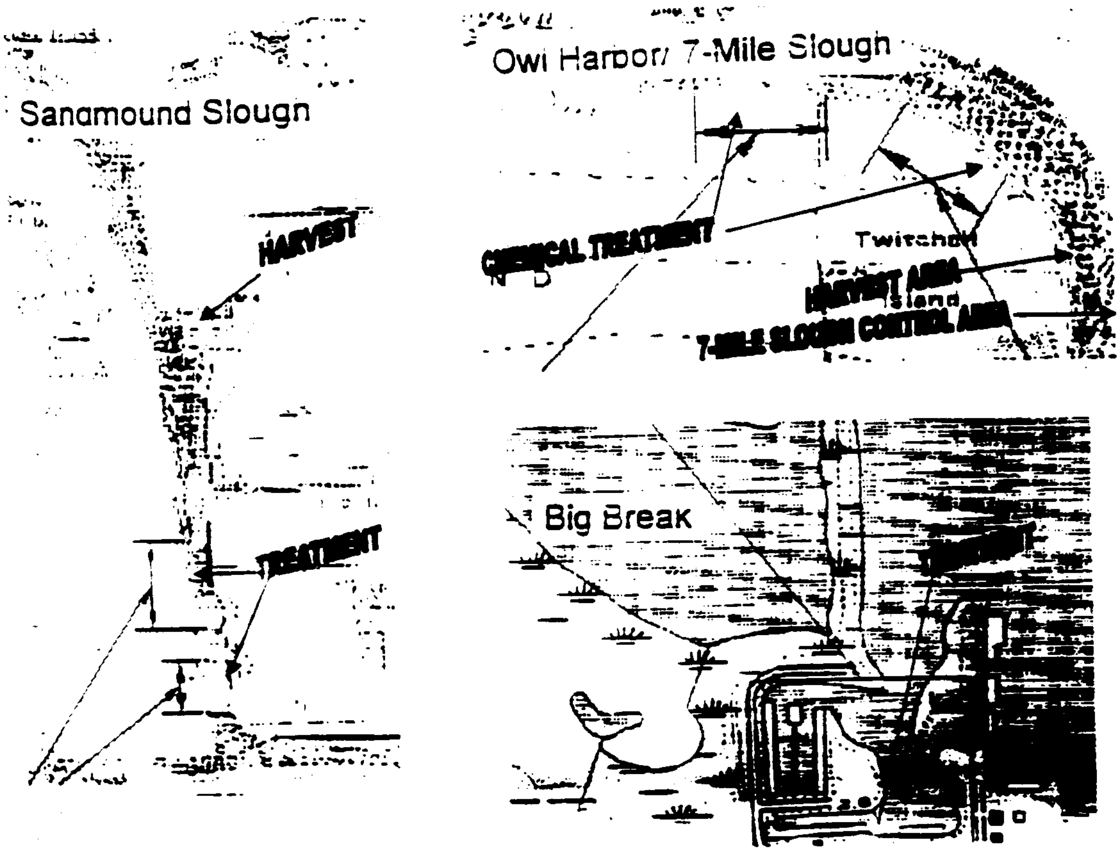


Fig. 2. Control and Treatment site locations in Sandmound Slough, Owl Harbor, Big Break and White Slough. The control site in Big Break is off the map about 1 km to the right (East) of the treatment site.

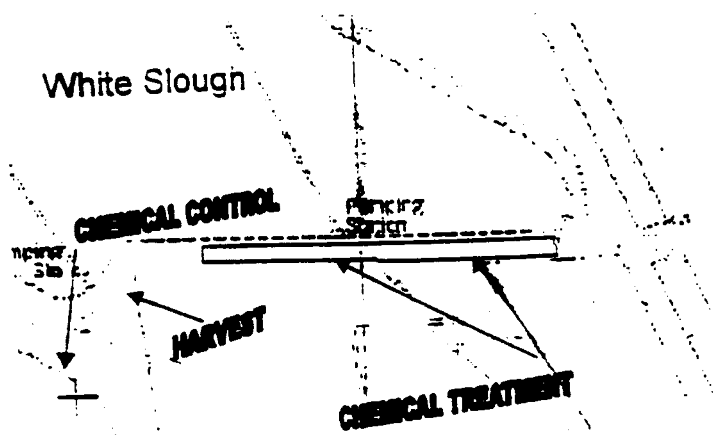


Fig. 2. Control and treatment site locations in Sandmound Slough, Owl Harbor/7-Mile Slough, White Slough and Big Break. The control site in Big Break is off the map about 1 km to the right (East) of the treatment site.

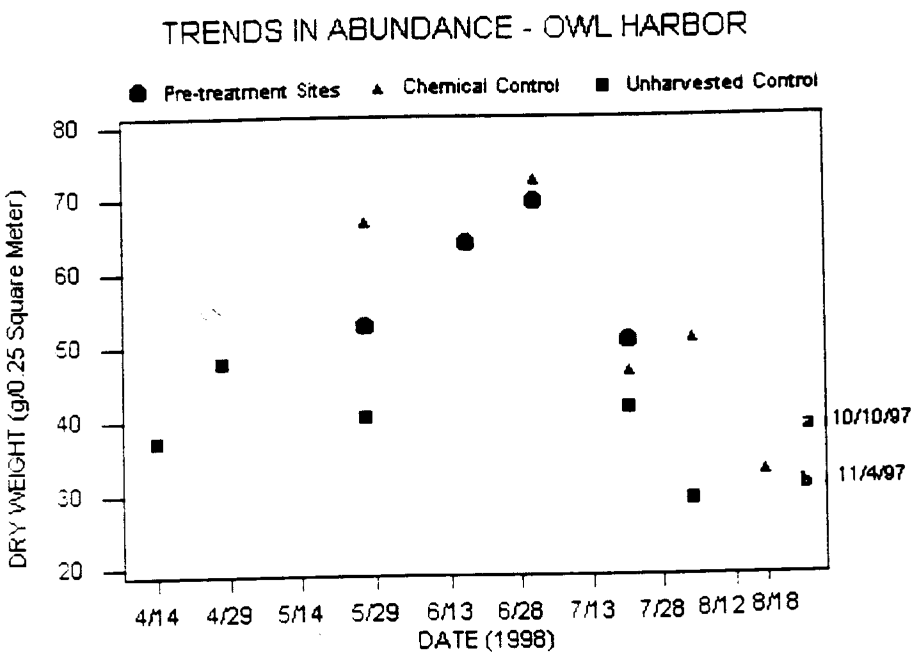


Fig. 3. Trends in mean dry weights of *Egeria* in Owl Harbor and vicinity. The symbols A and b indicate the dry weight of *Egeria* in the unharvested site in October and November, 1997 respectively.

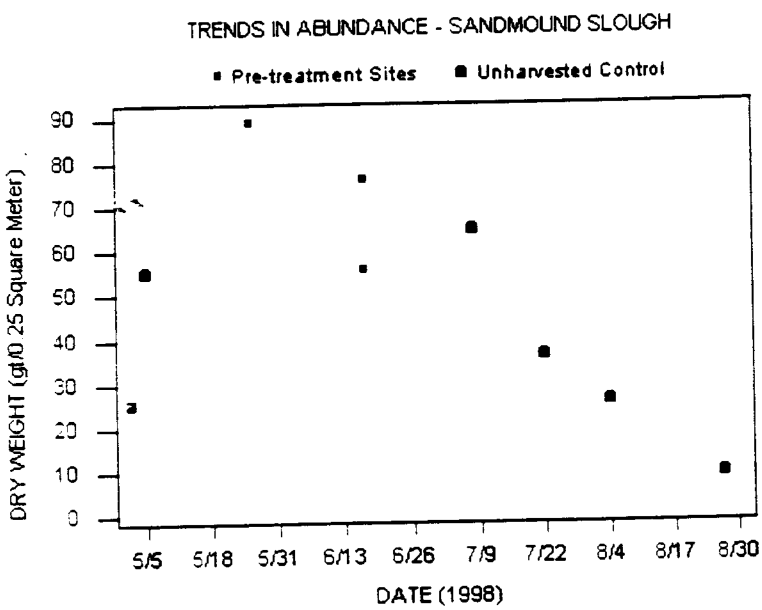


Fig. 4. Trends in mean *Egeria* density in Sandmound Slough. The letter a indicates the mean densities estimated in the unharvested site in October and November, 1997. These means were almost identical.

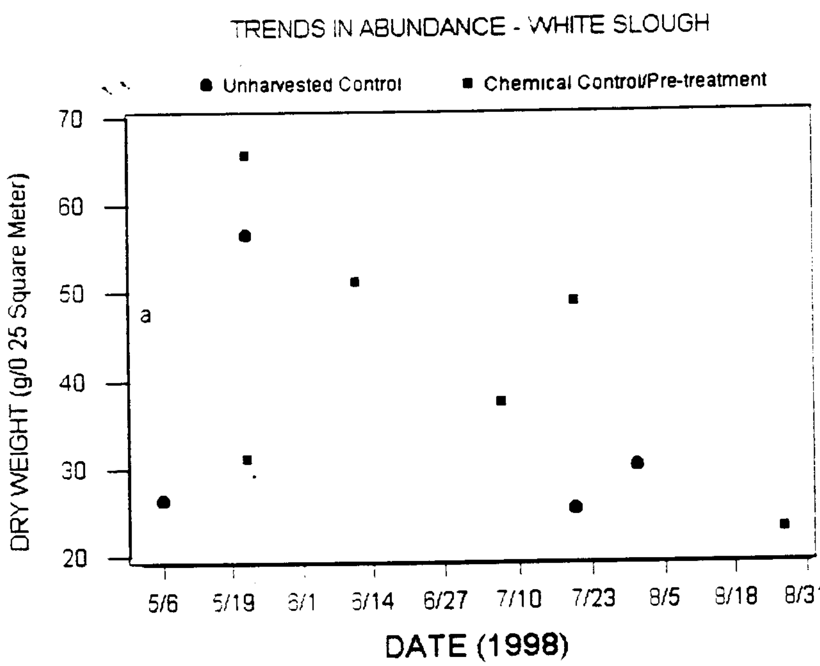


Fig. 5. Trends in mean *Egeria* density in White Slough. The letter a indicates mean density i the unharvested site in October, 1997.

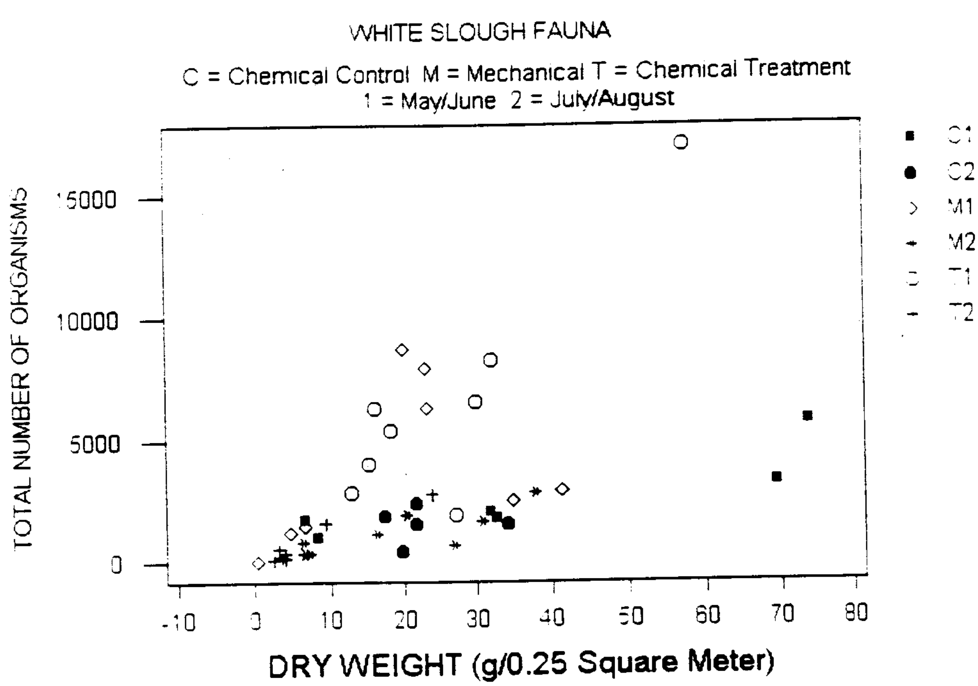


Fig. 6. Relationships between the total number of organisms and dry weight of *Egeria* i samples taken in White Slough between May and August, 1998. Two linear relationships ar apparent. The relationship with the lower slope (solid circles and squares) is characteristic c site C (chemical control area), at both sampling times. At other sites and times the relationshi switches between a lower and higher slope.

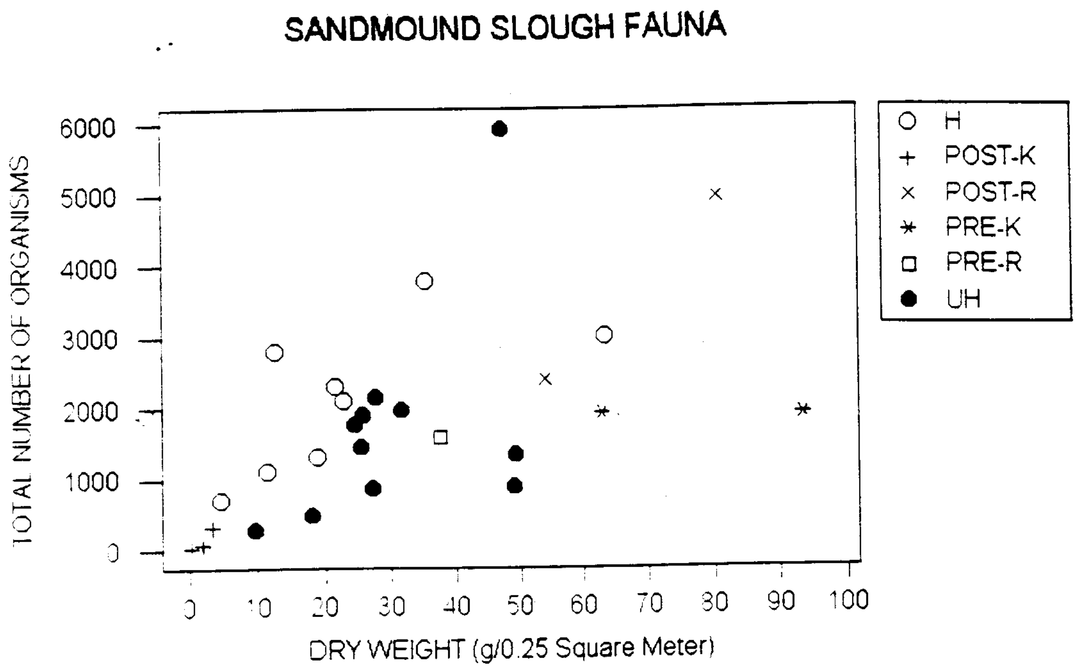


Fig. 7. Relationship between total number of organisms and dry weight of *E. densa* i Sandmound Slough between May and August, 1998 in four treatment sites (harvestec unharvested, Reward, Komeen). H – harvested site, POST-K – Komeen site after treatmen POST-R – Reward site after treatment, PRE-K – Komeen site, before treatment, PRE-R Reward site, before treatment, UH – unharvested site. Total numbers of organisms per dı weight tend to be lower in the unharvested (UH) site than in the adjoining harvested site.

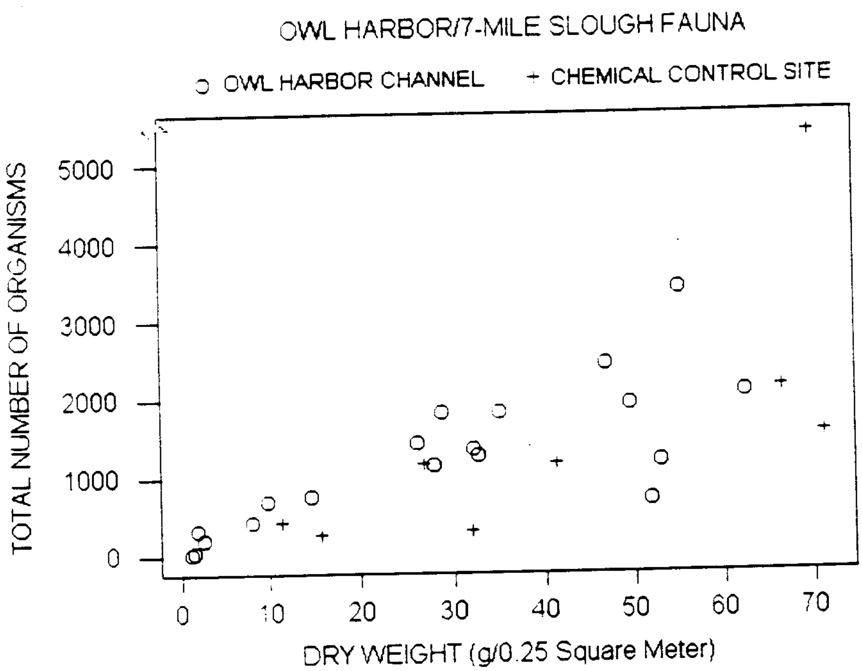


Fig. 8. Relationship between total number of organisms and *E. densa* dry weight in Ow Harbor/7-Mile slough sites. The Owl Harbor sites are within the 7-Mile Slough. The chemica control site (+) is just outside of the slough in the Sacramento River. Total number c organisms per dry weight of *E. densa* tend to be lower in the chemical control site.

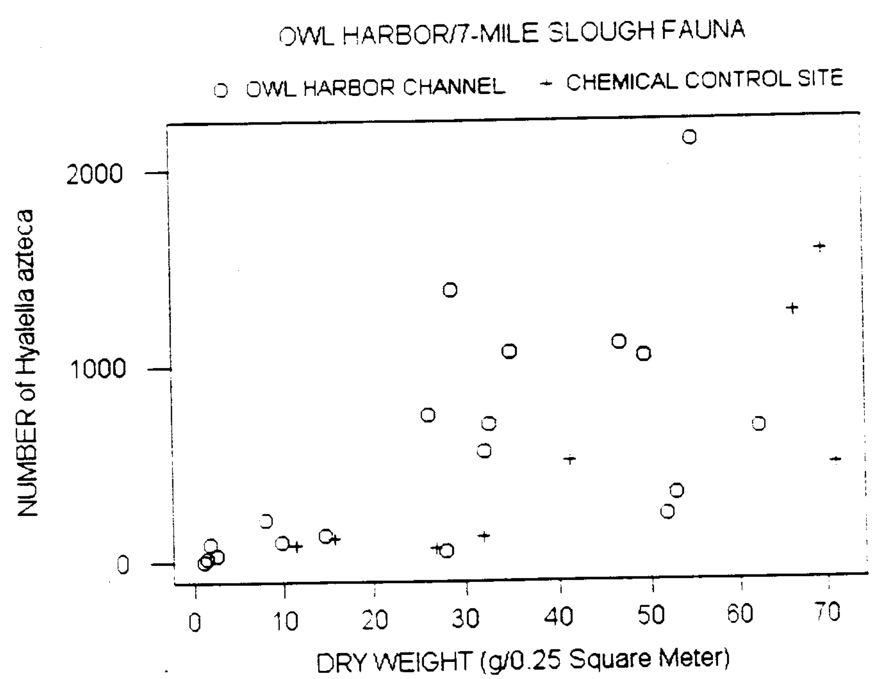


Fig. 9. Relationship between the numbers of the amphipod *Hyalella azteca* and *E. densa* d weight in Owl Harbor/7-Mile slough sites. The Owl Harbor sites are within the 7-Mile Sloug The chemical control site (+) is just outside of the slough in the Sacramento River. The tot number of amphipods per dry weight of *E. densa* tends to be lower in the chemical control sit

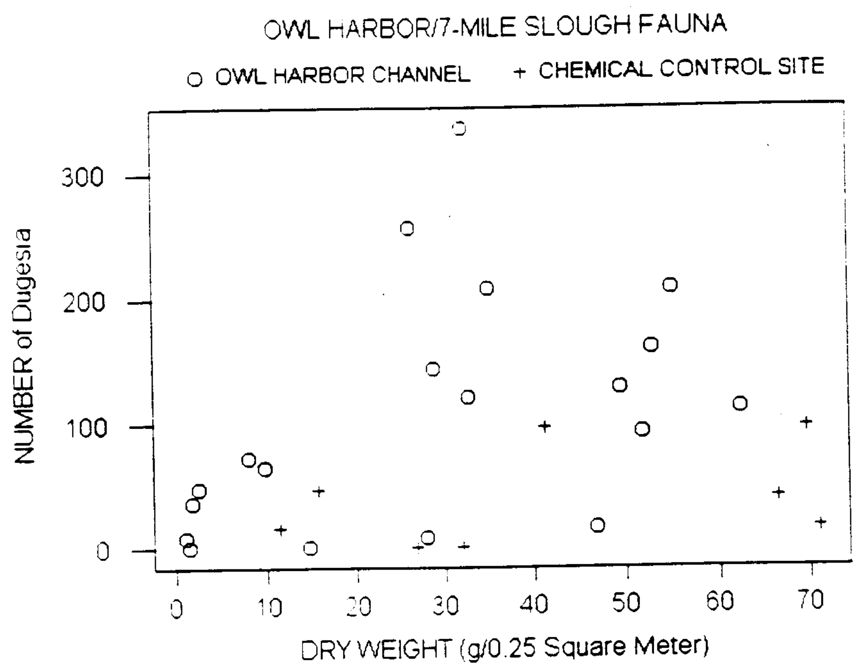


Fig. 10. Relationship between the numbers of the flatworm *Dugesia sp.* and *E. densa* dr weight in Owl Harbor/7-Mile slough sites. The Owl Harbor sites are within the 7-Mile Slougt The chemical control site (+) is just outside of the slough in the Sacramento River. The tot: number of flatworms per dry weight of *E. densa* tends to be lower in the chemical control site.

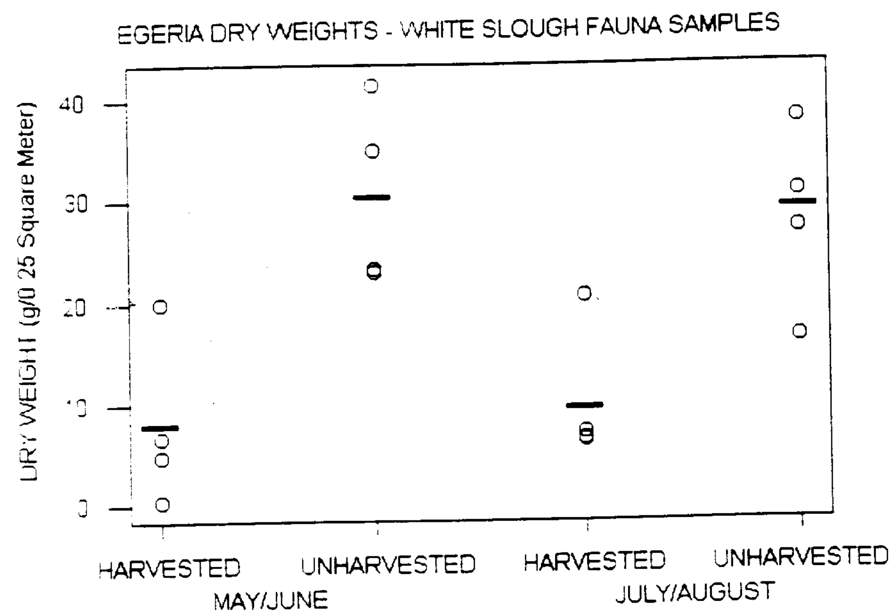


Fig. 11. Dry weights of *Egeria* samples taken for estimation of faunal abundance in harvested and unharvested areas in White Slough. Open circles are raw data, horizontal bars are means. Differences between times (May/June vs. July/August) are not significant. Differences between treatments (harvested vs. unharvested) are significant. Note the close similarity of means within the harvested and unharvested sites sampled at different times.

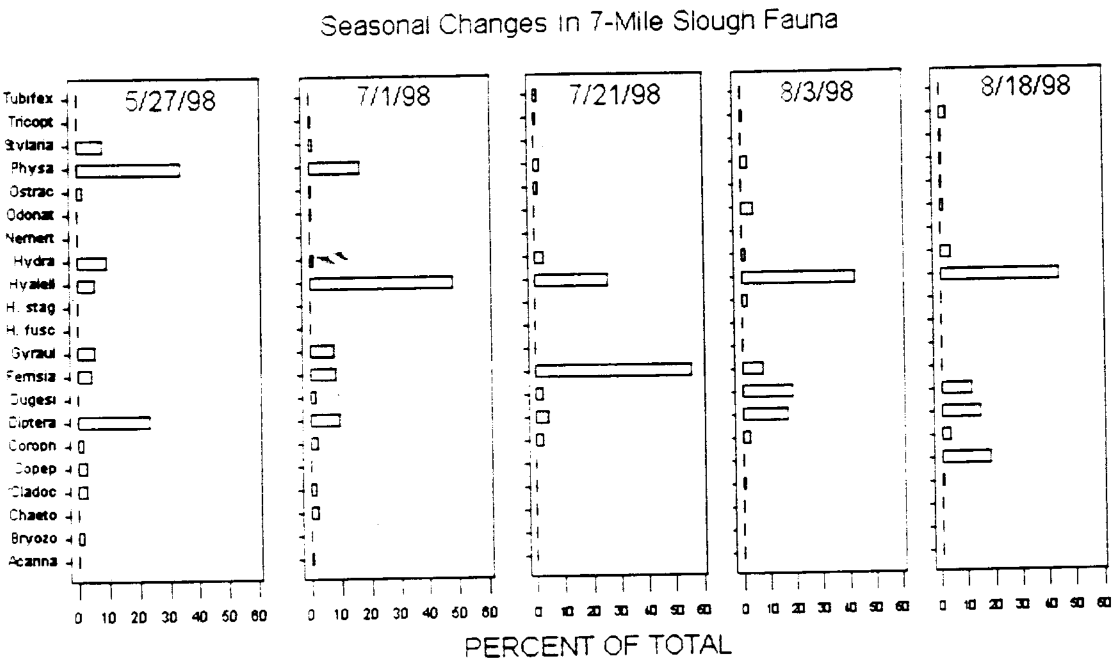


Fig. 12. Faunal changes in the Owl Harbor/7 Mile Slough chemical control site between May and August, 1998. Horizontal bars are percentages of the total sample represented by a particular taxon. Note the changes in numerically dominant species.

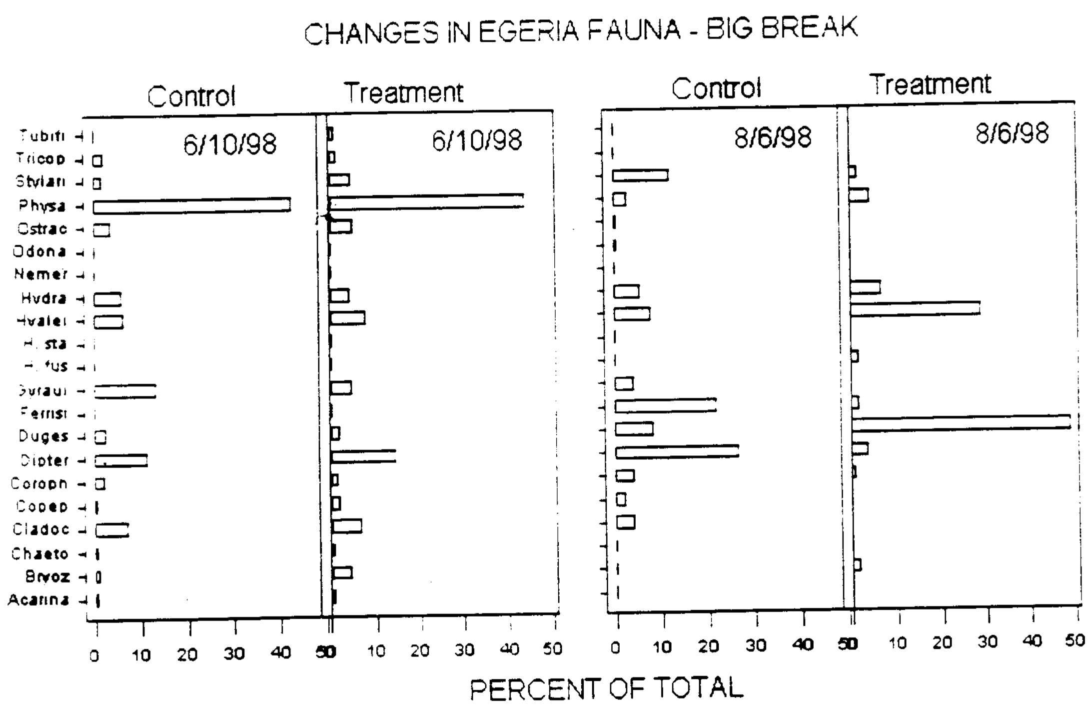


Fig. 13. Faunal changes in Big Break control and treatment sites before (6/10/98) and after (8/6/98 treatment with Sonar. Horizontal bars are percentages of the total sample represented by a particula taxon.

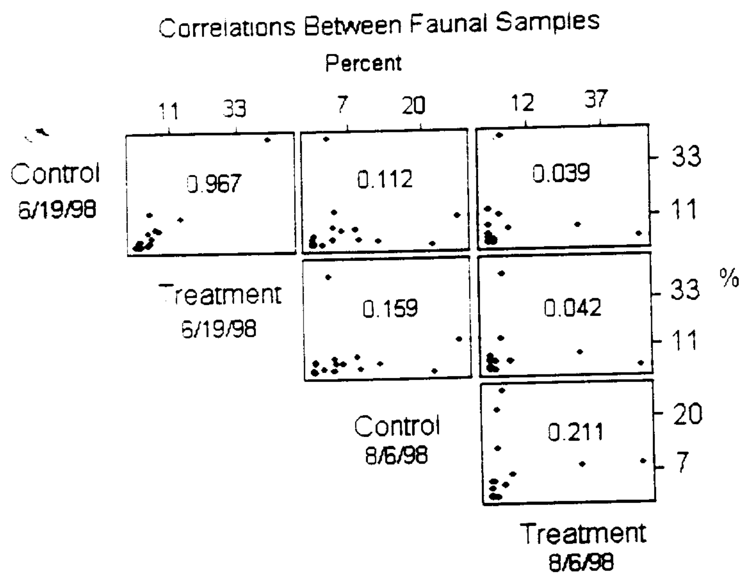
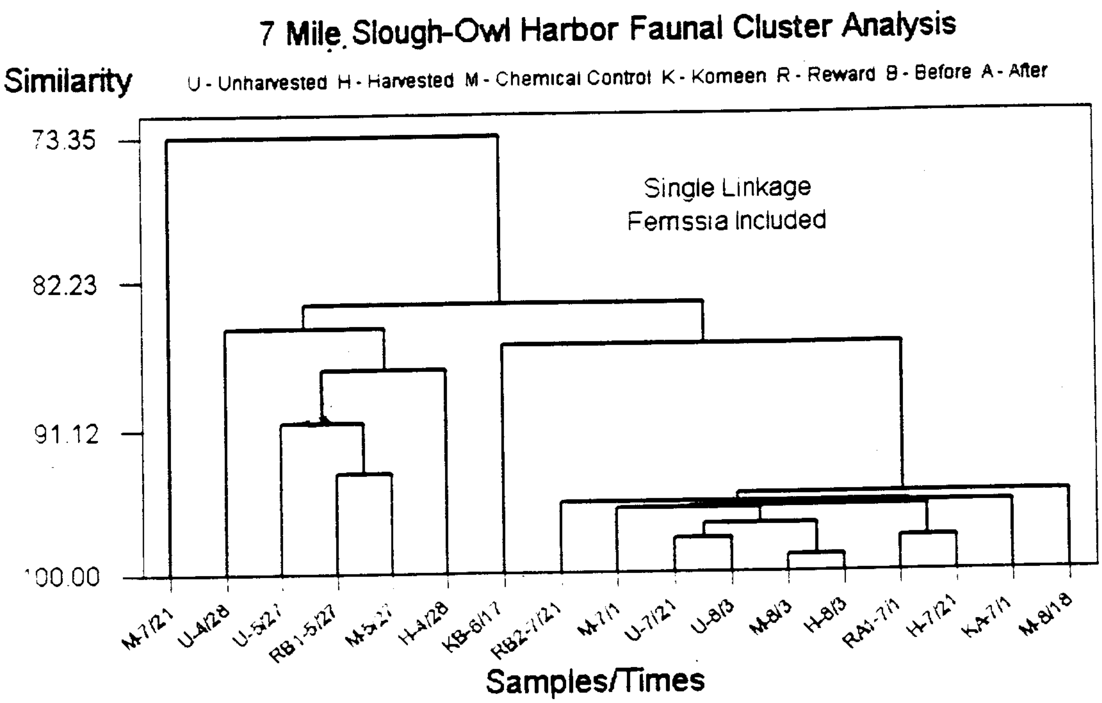


Fig. 14. Matrix plot and correlations between Big Break faunal percentages in treatment and contr sites before and after treatment with Sonar. The high correlation (0.967) between the control an treatment site sampled on 6/10/98 is significant ($p < 0.001$). All other correlations are not significant.



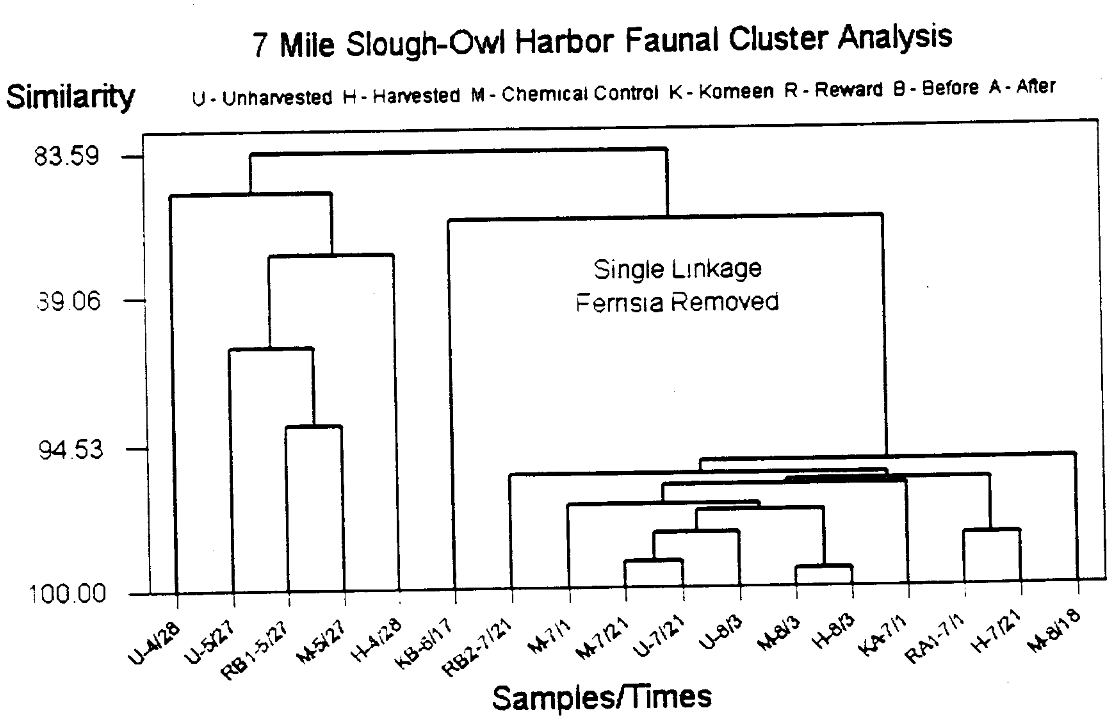
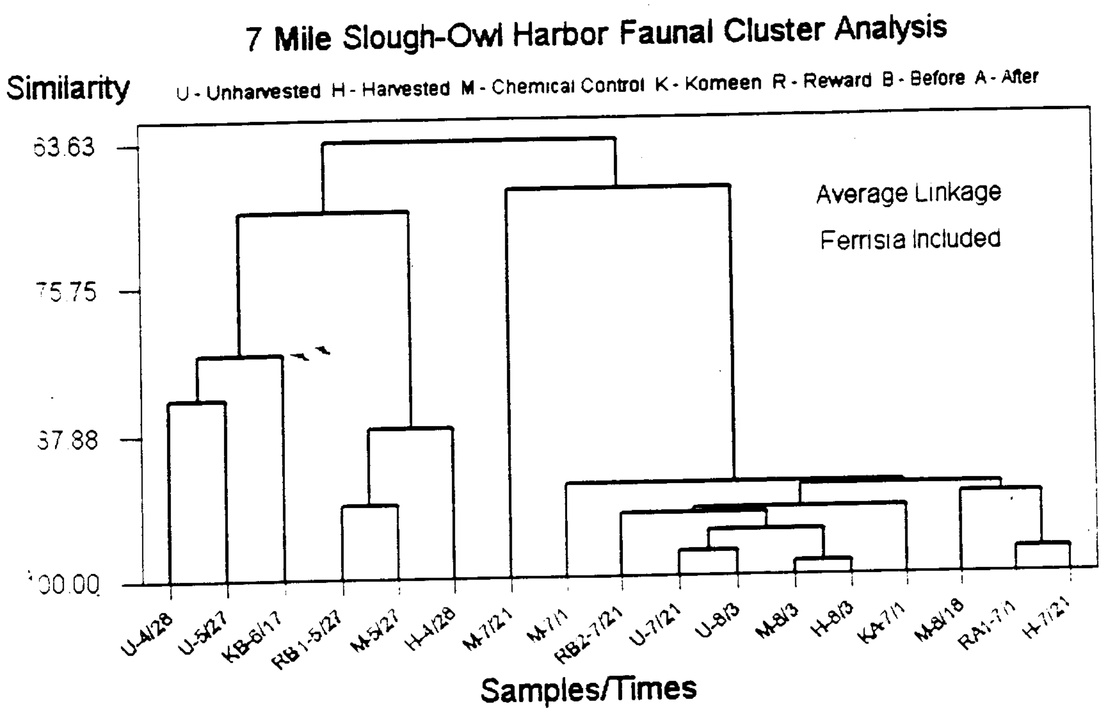


Fig. 15. Cluster analysis of Owl Harbor/7-Mile Slough Fauna. Upper figure: *Ferrisia* include sample M-7/21 strongly dissimilar to other samples. Lower figure: *Ferrisia* removed from all sample

sample M-7/21 nested within July/August sample group. Clusters determined by single linkage method.



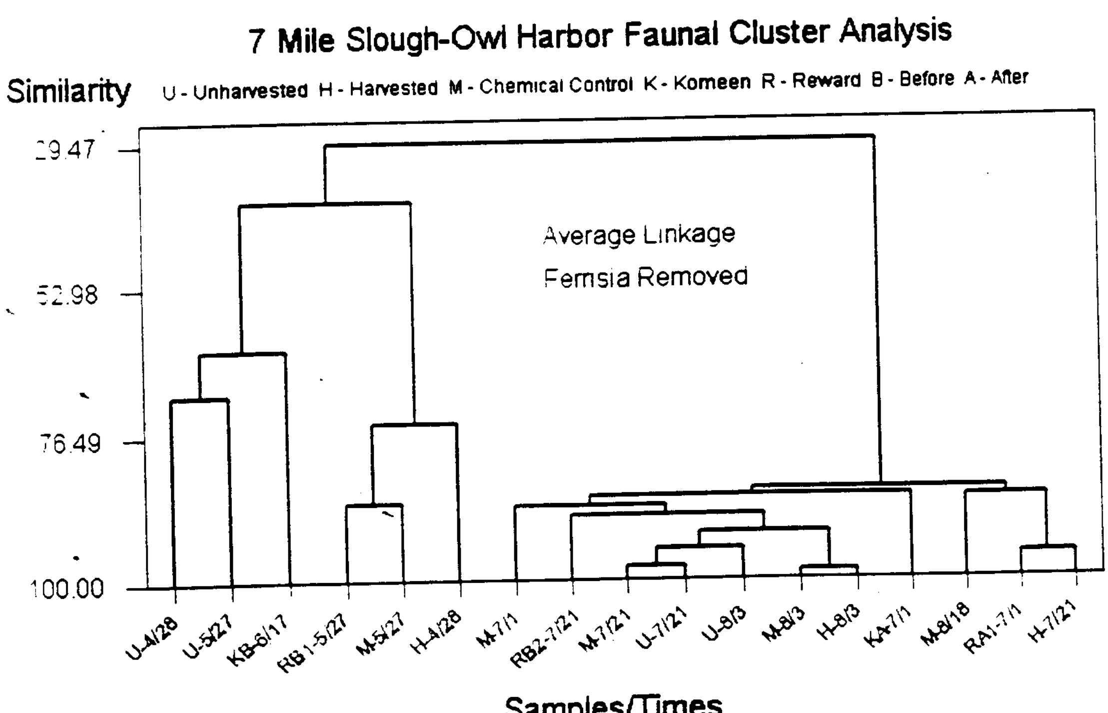
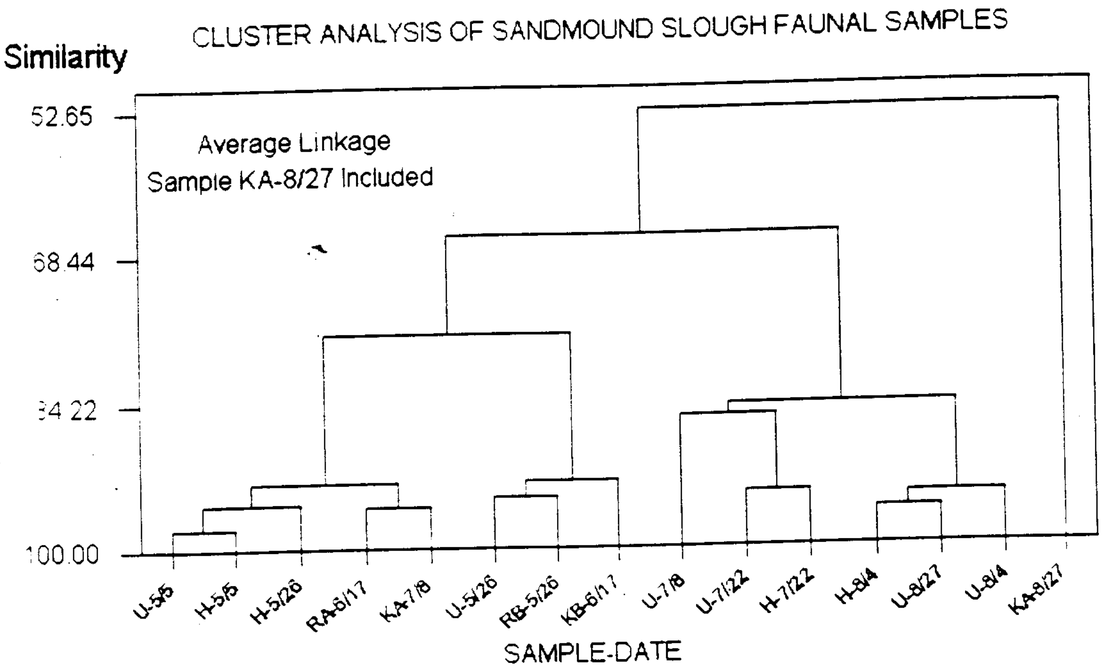


Fig. 16. Cluster analysis of Owl Harbor/7-Mile Slough Fauna. Upper figure: *Ferrisia* included, sample M-7/21 strongly dissimilar to other samples. Lower figure: *Ferrisia* removed from all samples, sample M-7/21 nested within July/August sample group. Clusters determined by average linkage method. Note position of sample KB-6/17 differs from Fig. 15.



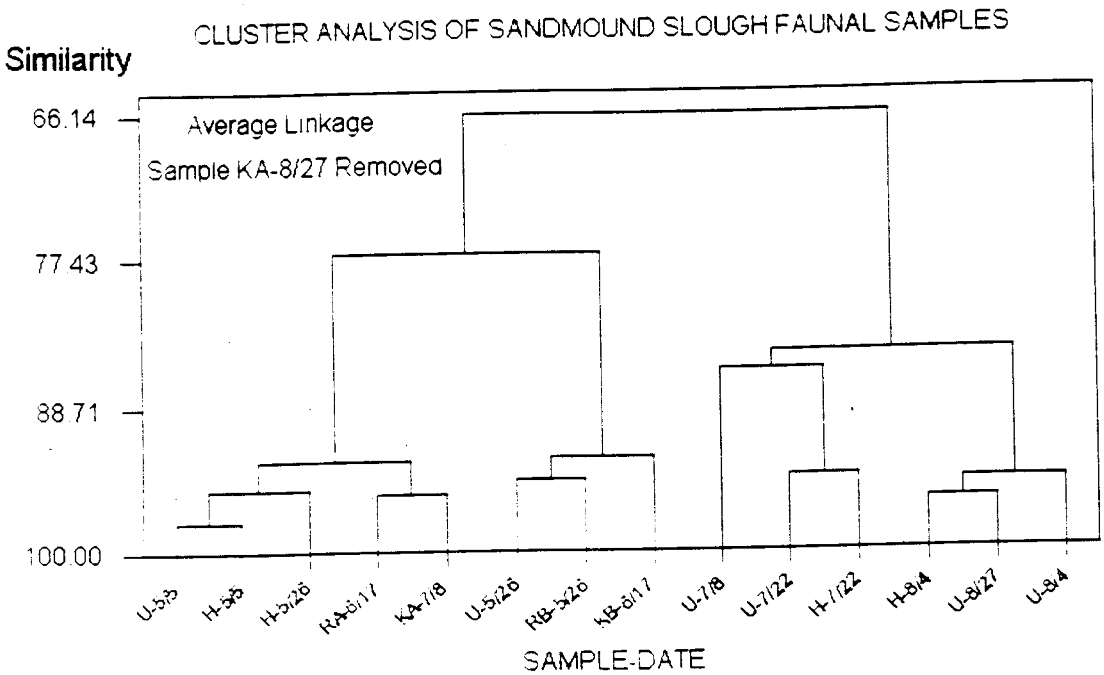


Fig. 17. Cluster analysis of Sandmound Slough fauna. Upper figure: Sample KA-8/27 dominated by large numbers of the flatworm *Dugesia* and the oligochaete *Tubifex* is distinct from other samples. Removal of both species did not change cluster arrangements. Removal of sample KA-8/27 conserves cluster arrangements. Note mixture of dates in major clusters.

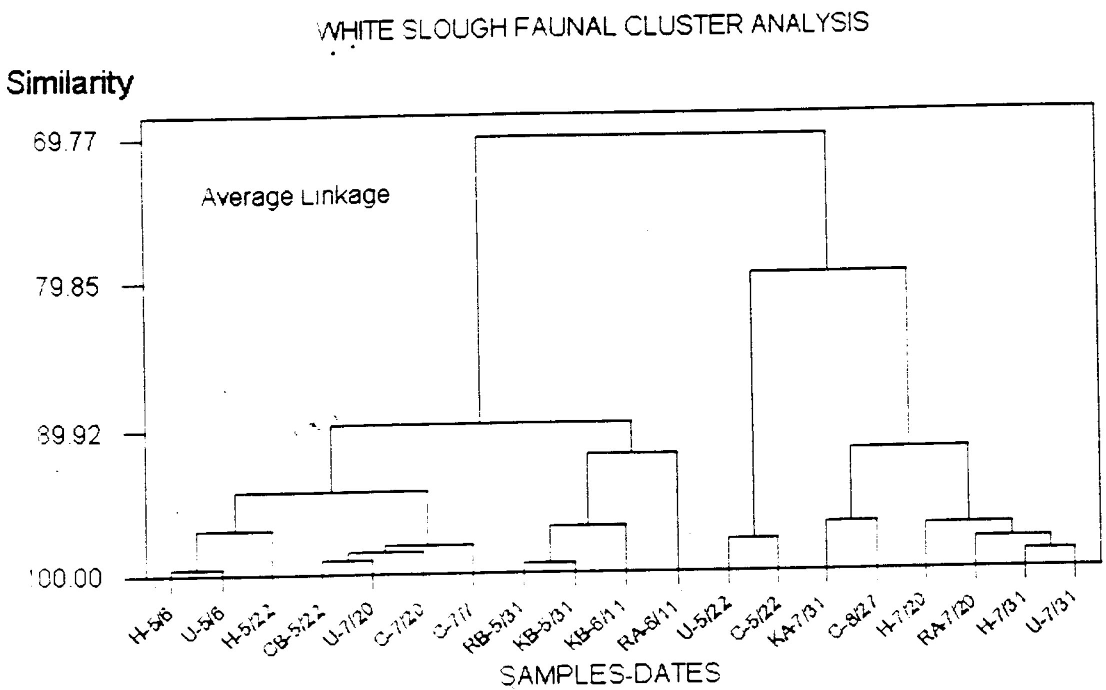


Fig. 18. Cluster analysis of White Slough fauna. Note mixture of dates in major clusters.

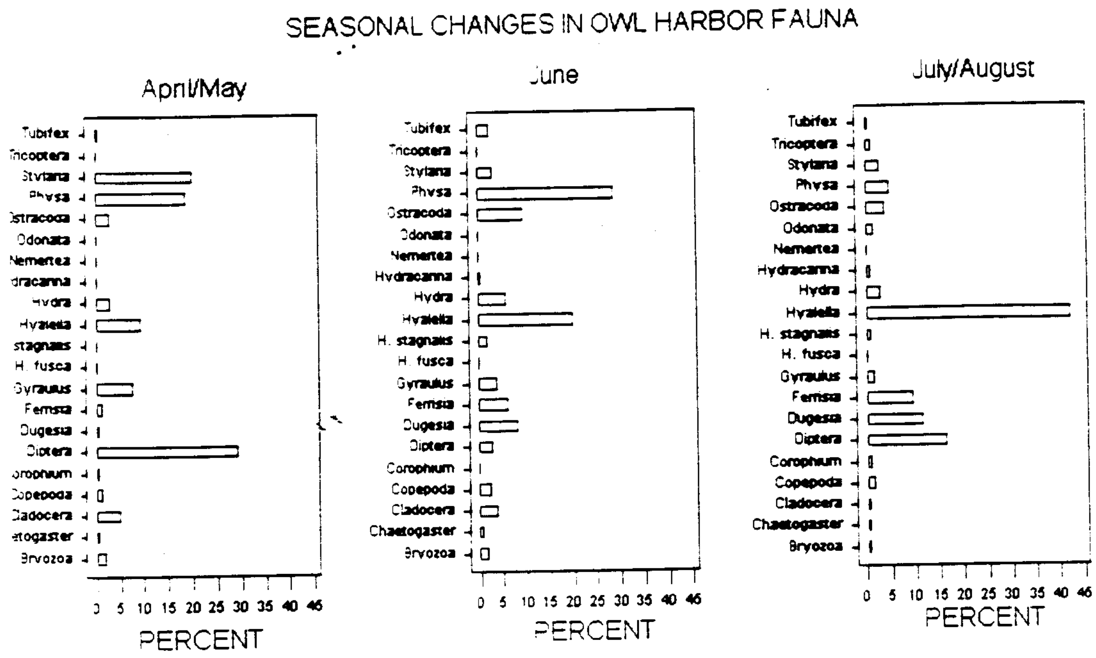


Fig. 19. Seasonal changes in *E. densa* fauna in Owl Harbor/7 Mile Slough in 1998. Major changes include decreases in *Physa*, *Stylaria* and Diptera, and increases in *Hyalella azteca*, *Dugesia*, and *Ferrisia*.